Standard Communications Protocol

for Traffic Signals in California

Specification and Implementation Requirements

As Required by Assembly Bill No. 3418

November 28, 1995

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Foreword

California Assembly Bill No. 3418 (AB 3418) became law on January 1, 1995. The bill requires all new or upgraded traffic signal controllers installed in California after January 1, 1996, to incorporate a standard communications protocol. As the State agency responsible for implementation of the bill, Caltrans has published this specification for use by developers of traffic signal controller software and by California users of traffic signal controllers. This document was developed by a committee composed of traffic signal users, developers, and designers.

AB 3418 is intended to facilitate improved coordination and management of traffic signals in situations where adjacent signals are operated by different agencies. The protocol specified herein allows basic communication messages to be sent to and from multiple traffic signal controllers on the same communications channel, even if the controllers are of different types or utilize different software.

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Section 1 - Background and Purpose

1.1 The Problem Addressed by AB 3418

In most urban areas, and even in rural areas, adjacent jurisdictions abut and it is often necessary, or at least desirable, for adjacent traffic signals to communicate with a master operated by another agency. In the past, that communication was generally not possible due to incompatible communications protocols used by the signal controllers adopted by different operating agencies.

Examples of adjacent signals operated by different agencies include freeway ramp signals adjacent to city signals on a local street, signals on a State or County highway adjacent to City signals, signals operated by two adjacent cities, and County signals in an unincorporated area adjacent to City signals. Improved coordination of such traffic signals is the most common reason for needing a standard communications protocol in the traffic signal controllers.

1.2 The Origins of AB 3418

In 1992, working with other local transportation and enforcement agencies, Riverside County took the lead in addressing the problem of multijurisdictional signal coordination as part of a bigger effort to improve overall traffic operations and safety in the County. A traffic signal coordination committee was formed to identify issues related to coordination of different types of traffic signal controllers operated by different agencies.

The findings of that committee lead the Riverside County Transportation Agency to conclude that State legislation would be necessary to provide a general solution to the problem. The Agency created the first draft of such legislation and found legislative support for its adoption. The result was the passage of Assembly Bill 3418 in September, 1994.

The full text of the bill is enclosed as Appendix B. In essence, it requires that all traffic signal controllers installed or upgraded in California after January 1, 1996, include a standard communications protocol capable of two-way communications.

1.3 The Origins of This Document

Caltrans is the State agency responsible for implementing Assembly Bill 3418. To assist in that process, Caltrans elected to use a committee composed of representatives of interested parties. That committee, referred to as the AB 3418 Implementation Committee, developed the standard protocol to be used in controllers installed after January 1, 1996, as required by the legislation. The committee membership roster is enclosed as Appendix B. The fifteen member committee included a broad cross section of organizations involved in traffic signal

design, development, and operation in California. It included representatives of cities, counties, Caltrans, controller manufacturers and software developers, and consultants.

Although AB 3418 is explicit about the date it is to take effect, the nature of the required communications protocol and how it is to be implemented are not explicitly stated. The drafters of the legislation intended that such details be developed by a committee such as the AB 3418 Implementation Committee. This document is the result of that committee's deliberations.

1.4 The Intent of the Legislation

Assembly Bill No. 3418 is intended to facilitate the coordination of traffic signals operated by different jurisdictions. The following are the key elements and repercussions of the legislation for agencies operating traffic signals in California..

- AB 3418 establishes a means by which traffic signal controllers installed after January 1, 1996, can be communicated with through a non-proprietary, equipment independent, communications protocol (i.e. a standard protocol).

- There is no requirement to replace or retrofit existing controllers that are not being upgraded or replaced for other reasons.

- The AB 3418 standard protocol supports remote control and monitoring functions only. The control function is to enable the maintenance of signal coordination with adjacent intersections. The monitoring function is to allow verification of controller operation.

- The AB 3418 standard protocol does not provide comprehensive support of all control functions, including uploading and downloading.

- The AB 3418 standard protocol does not replace or supersede existing communications protocols.

- The AB 3418 standard protocol may coexist in a controller with any proprietary or otherwise non-standard protocol.

1.5 The Purpose of This Document

This document has two primary purposes:

- Provide developers of traffic signal control software with details of the standard communications protocol required by AB 3418.

- Provide traffic signal controller users with guidance as to their obligations, options, and opportunities under AB 3418.

Section 2 - Intended Use of the Standard Protocol

2.1 Protocol Use

The AB 3418 protocol is intended for use at traffic signals which require remote operation, coordination, or monitoring. AB 3418 requires provision of the standard protocol in all new and upgraded controllers. The controller may use the protocol to communicate with another controller, with a field master, or with a remote computer. Such other controller, master, or computer may be owned or operated by the same or a different agency.

An agency other than the signal owner may need such communication for the purpose of maintaining or improving signal coordination, or for monitoring the operation of a signal in which two or more agencies have a shared interest. Two agencies may have a shared interest in a signal for a variety of reasons, including the following.

- The signal is part of a coordinated group of signals which spans the jurisdictional boundary.
- The two agencies share ownership of the intersection (e.g. each owns one or more legs of the intersection).
- Traffic queued at the signal can affect traffic operations in the adjacent jurisdiction, or the signal otherwise directly affects a street or ramp operated by another agency.
- One agency undertakes signal operation or maintenance on behalf of the other agency.
- The signal provides priority or other special treatment for special vehicles (e.g. transit or emergency vehicles) operated by the other agency.

Use of the protocol will not normally be necessary or appropriate at a traffic signal in which only one agency has an interest and which is not coordinated with any signals operated by another agency. However, the owner of such a signal may choose to use the protocol for its own purposes. Most often, a more comprehensive communication protocol will be available in the controller software for communications with a field master or central computer operating software matched to that particular controller software version.

2.2 Information Able to be Transmitted

Given the legislative requirements and the promise of the National Transportation Control/ITS Communications Protocol (NTCIP) being available in the future, the AB 3418 Implementation Committee decided to limit the AB 3418 protocol message set to a very simple subset of the messages commonly communicated to and from a traffic signal controller. There is, for example, no ability to upload or download signal timings, and second-by-second control from a central computer is not supported.

The information which can be exchanged via the AB 3418 protocol is limited to the following.

To controller -

- Current day, date, and time to be used to set the controller's clock.
- The number of a locally stored coordination timing pattern (or free, flash, or standby mode) to be operated.

From controller -

- The number of the current coordination pattern (including free or flash).
- The local cycle zero point.
- Any current alarms (e.g. detector fault, flash, preempt, etc.).
- The current green status of up to eight phases.

The protocol specification includes an optional capability to gather system detector data, but this function may not be available in all controllers.

2.3 Typical Applications

The following are some of the applications which the AB 3418 protocol is intended to address.

- One agency sets the clock at another agency's controller to ensure it is synchronized with the agency's own controllers with which it is coordinated.

- One agency directs another agency's controller to use a particular coordination timing pattern, where such pattern has been selected manually, by time-of-day, or using traffic responsive pattern selection.

- One agency monitors the status of another agency's controller to confirm that it is operating in accordance with a coordination timing pattern developed jointly by the two agencies.

- One agency monitors another agency's signal so as to display and analyze a real-time map of a coordinated signal system containing signals in both jurisdictions.

- One agency monitors another agency's controller for alarms and faults because it operates or maintains the signal under contract to the other agency.

The AB 3418 standard protocol, in its minimum required configuration, will not support many of the functions commonly supported by modern computerized signal management systems, including the following.

- Uploading and downloading of signal timings and parameters from a computer.

- Gathering system detector data for traffic responsive plan selection (this is an optional function).

- Sending coordinating cycle pulses or "seven wire interconnect" pulses.

- Second-by-second phase control of a signal from a central computer.

- Detailed intersection graphical display support (e.g. phase call status).

Traffic responsive pattern selection (TRPS) is somewhat supported in that a controller can be commanded to change patterns. The protocol does not support gathering system detector data (e.g. counts and occupancy) except as an optional feature. Therefore, TRPS can be used for coordinated signal systems spanning two jurisdictions, but if either agency does not have the optional system detector data feature, then only system detectors within one of the jurisdictions can be used for making the pattern selection decision.

The above discussion assumes that the two agencies involved utilize different and incompatible controller types or software packages, that could not communicate with the same master using their native communications protocols. It is equally applicable to different controller types or software packages operated by a single agency.

2.4 Signal Timing and Control

AB 3418 requires all new or upgraded controllers to support a standard communications protocol. However, it does not preclude the existence or use of other protocols in the controller. The controller can continue to support and use any other protocol(s) including proprietary protocols.

While the controller must support the AB 3418 protocol, use of the protocol is entirely up to the agency(s) involved in the operation of a signal. If a decision is made to use the AB 3418 protocol, how it is used, which of the defined messages are transmitted to and from the controller, and what timing patterns are used, are not dictated by AB 3418. Again, such decisions are entirely up to the agency(s) involved in the operation of the signal. If two

agencies have an interest in a signal, then those agencies may want to have the non-owning agency monitor or control the signal using the AB 3418 protocol in order to improve signal coordination, or for some other purpose. The AB 3418 protocol will enable those agencies to do that, whereas other protocols available in the controllers may not.

Section 3 - Requirements for Agencies Operating Traffic Signals

3.1 Agencies Subject to AB 3418

The legislation applies to all agencies installing or upgrading a traffic signal controller for traffic control in California after January 1, 1996. Such agencies include cities, counties, and Caltrans. In cases where the controller is installed or upgraded by an agency other than the agency which then operates the controller, the agency which installs or upgrades the controller is responsible for ensuring that the controller has a protocol which meets this specification.

3.2 Basic Requirement

All traffic signal controllers *newly installed or upgraded* for traffic control in California after January 1, 1996, shall have, available for use, a standard communications protocol which meets the requirements of this specification.

3.3 Signal Controllers Subject to AB

The legislation states that the protocol shall be available for all signal controllers that are "newly installed or upgraded . . . after January 1, 1996". This is interpreted as applying to any controller which meets either of the following criteria.

- The controller has not previously been used by the installing or operating agency (even if previously used by another agency) and is put into service (switched on) for the first time at this site, after January 1, 1996.

- The controller is the subject of an upgrade which is put into service (switched on) for the first time at this site, after January 1, 1996. Such upgrade includes installation of a substantially new version of the controller software. However, controller software revisions which are primarily for the purpose of correcting software errors or other minor alterations, and which do not provide significant additional or different functionality, are not viewed as upgrades for the purpose of application of AB 3418.

There is no requirement to replace or retrofit existing controllers that are not being upgraded or replaced for other reasons, even if other signal components at the site are being upgraded. Also excluded are controllers merely being relocated between sites for which the same agency is responsible. However, a controller previously used by a different agency at a different site and now being used for the first time by this agency (after January 1, 1996), is subject to AB 3418.

3.4 Applicability to Different Controller Types

There is no distinction made between different types of controllers, including those adhering to the NEMA TS-1 or TS-2 standards and those adhering to Caltrans' Model 170 or 2070 specifications. All controllers are treated equally and the protocol is equally applicable to NEMA, Model 170 and 2070 controllers, as well as to controller software developed by any agency, software vendor, controller manufacturer, or other party.

There is no new or changed restriction placed on any agency as to which type of controller (e.g. NEMA or Model 170) is used in any installation due to AB 3418. AB 3418 may enable more choice in controller type in some situations, but that is entirely up to the agency(s) involved in each installation.

3.5 Controller or Software Procurement Documents

Each agency procuring a new or upgraded signal controller for installation in California after January 1, 1996, must specify that the controller contain software which provides the AB 3418 protocol. Agencies should include a suitable clause in specifications for all controller and controller software procurement contracts which may result in the purchase of a controller or software which will be installed after January 1, 1996. The following clause is suggested as suitable for inclusion in a technical specification.

> *The signal controller shall include a standard communications protocol which meets or exceeds the requirements of AB 3418 as specified by Caltrans. This protocol shall be selectable by the user as an alternative to the normal protocol when communications with a master supporting the AB 3418 protocol is desired. The AB 3418 protocol in the controller shall not substitute for or alter the operation of the normal communications protocol without the written approval of the Engineer. The normal communications protocol shall be the default protocol enabled on controller start up. Contractor shall certify, in writing, that the controller software complies with AB 3418.*

If the ability to upload system detector data is required, a sentence similar to the following should be added to the specification.

> *The protocol shall include support for uploading system detector data using the optional message defined for that purpose.*

If the agency plans to use the AB 3418 protocol, it may also want to specify inclusion of a master version of the protocol in the controller software, a field master, or a central computer. AB 3418 does not require a master version of the AB 3418 protocol to be provided.

Agencies planning to use the AB 3418 protocol are encouraged to require demonstration tests of its operation in the intended setting prior to purchase of controllers or controller software. Agencies are also reminded that there are several potential obstacles to successful communications between traffic signals other than the communications protocol. Some examples include incompatible, unreliable, or excessively slow communications media or data transmission equipment.

3.6 Controller Versus Master Software

The legislation explicitly addresses only signal controllers, and makes no reference to masters or computers. Although the law requires an agency only to install controllers which support the protocol, any agency wishing to take advantage of the standard protocol will need to develop or purchase master software which also supports the protocol. The protocol assumes that a controller will be polled by a master, and messages are defined as "commands" from the master, and "replies" from the controller. Even if another controller is to be used as a "master", it will require additional communications functionality over and above that required by AB 3418. A "master" will most often be a field master or central computer, but may be another local controller.

It is anticipated that developers of master software packages intended for use in California will incorporate a master version of the protocol in their master software packages. Many of the master software developers also develop controller software, and some may offer controller packages which can act as both a master and controller for the purpose of communications. Some may enable controller messages to be passed to and from a field master or computer via another controller. Such functionality is beyond the purview of AB 3418. However, AB 3418 will ensure that any controller equipped with the protocol will be able to communicate with any master in any arrangement designed to use the standard protocol.

3.7 Multiple Communications Ports

There is no requirement for a controller to have or support more than one communications port. However, depending on the intended application, an agency may choose to purchase controllers which provide and support two (or more) ports. If more than one port is provided, the AB 3418 protocol must be available via at least one port.

3.8 Requirement for the Standard Protocol to be Resident in the Controller

Virtually all controller software packages currently provide a communications protocol for communications with a matched master software package. Such protocols may continue to coexist in controller software packages together with the new AB 3418 protocol. The controller user is able to choose, by data entry, which protocol to use at any time, or if the

controller is so equipped, both may be able to be used at once using two communications ports.

Prior to January 1, 1997, it is sufficient for an agency to keep on hand two separate versions of the controller software, one with and one without the AB 3418 software. The compliant version would be installed only if and when needed. For controllers installed or upgraded after January 1, 1997, the AB 3418 protocol must be included in the controller software package used in the field, even if the operating agency has no current use for it.

This grace period provides additional time for software developers to fully integrate the standard protocol into their mainstream software package(s). Controllers installed or upgraded during this grace period and for which the AB 3418 protocol is contained in a separate version of the software not currently used at the intersection, need not be upgraded at January 1, 1997, to include the standard protocol at the intersection.

3.9 Additions to the Standard Protocol

A controller containing a communications protocol which otherwise meets all requirements of this specification, may incorporate, within that protocol, additional capabilities, providing such additional features are not necessary for, nor impair, use of the basic features required by this specification. A protocol may, for example, provide additional messages. In this way, the standard protocol may be a subset of a more comprehensive, and possibly proprietary, protocol.

3.10 Testing and Certification

Agencies procuring controllers or controller software are responsible for ensuring that controllers comply with this specification. It is recommended that controller or software suppliers be required to certify that their product meets the requirements of this specification. Caltrans will provide software developers with a test routine to aid in testing the operation of the standard protocol. However, use of that test routine does not ensure compliance, and no warranty is made or implied as to its efficacy in discovering faults in operation of the protocol. The State has no AB 3418 certification program.

3.11 Exemptions From AB 3418

The following controllers are exempt from the requirements of this specification.

- Controllers purchased prior to January 1, 1996, (but not installed until after that date) and for which no AB 3418 compliant version was available at the time of purchase and for which no AB 3418 compliant software upgrade is currently available at reasonable cost or within a reasonable time frame.

- Electromechanical or other controllers for which the AB 3418 protocol is not applicable or practical.

- Experimental controllers or software packages intended for short term use in a particular test site where AB 3418 would provide no benefit.

The following conditions do not exempt an agency from AB 3418, but do provide an exemption from the requirement (after January 1, 1997) that the standard protocol be resident in the controller at all times, even if not being used. This exemption allows a separate AB 3418 compliant version of the controller software to be kept on hand by the agency. This version may not provide all the functionality contained in the agency's normal software package, but could be used if the AB 3418 protocol is needed.

- The intent of AB 3418 is achieved by providing a master-to-master connection between two agencies' traffic signal systems, and such connection provides at least equal functionality to that provided by the AB 3418 protocol when resident in the controllers.

- Any unusual situation in which integration of the AB 3418 protocol into the normal software package would involve a significant financial or time penalty yet provide no benefit for the public or any agency.

Agencies installing or upgrading typical modern controllers are not exempt merely because they have no use for the AB 3418 protocol.

Section 4 - The Standard Protocol Specification

4.1 Overview of the Protocol

The protocol was based on the draft version of the National Transportation Control/ITS Communications Protocol (NTCIP) available at the time this specification was developed in 1995. NTCIP follows the guidelines of the International Organization for Standardization, Open Systems Interconnection Reference Model (RM-OSI), and defines protocols at layers 1 (physical), 2 (data link), 3 (network) and 7 (application). The AB 3418 protocol is a subset of the full NTCIP protocol, in that it does not require support for all NTCIP messages nor for data transmitted in multiple data packets.

At layer 1, the AB 3418 protocol defines both the RS-232-C and 1200 baud FSK modem standards for the physical communications link between the controller and master. At layer 2, the protocol defines an asynchronous data link control mechanism based on a subset of the High-level Data Link Control (HDLC) standard. The data are transmitted in "frames" containing start and end flags, the destination address, a message type indicator, the data being transmitted (the data packet), and a data integrity check sum (Cyclic Redundancy Check).

At layer 3, the AB 3418 protocol defines a connectionless direct communications link corresponding to NTCIP's Class B communications. Class B is a simple minimum overhead scheme for use between a controller and a master directly connected on the same communications link. At layer 7, the AB 3418 protocol defines basic messages composed of NTCIP message elements, and defines the protocol for initiating and responding to messages.

4.2 Physical Layer Definition

An RS-232-C Data Terminal Equipment (DTE) interface shall be provided for interconnecting to an external communications device at a minimum of 1200 bps. As defined in ISO/IEC 3309, the byte structure shall be 1 start bit, 8 data bits, and 1 stop bit. The signals, as a minimum, shall consist of:

Function	I/O
Earth Ground	
Transmit Data	O
Receive Data	I
Request To Send	O
Clear To Send	I
Logic Ground	

The data format shall be asynchronous, bit serial.

4.3 Data Link Layer Definition

4.3.1 Data Link Layer Service

The service provided by the AB 3418 Data Link Layer is the connectionless-mode service as defined in CCITT Rec. X.212, Clauses 1-7 (general) and 15-19. Within these clauses, those aspects dealing with Quality of Service shall not apply (this includes all of Clause 17 and applicable parts of the other clauses). In particular, the following aspects of these clauses are noted.

1) Clause 15 describes the features of the Data Link Layer service: all implementations shall support a DLSDU length of at least 515 bytes.

2) Clause 16, dealing with the model of the Data Link Layer service, shall apply with the additional assumptions that the service shall not duplicate SDUs nor exchange the order of SDUs.

3) Clause 18, dealing with the sequence of primitives, shall apply.

4) Clause 19, dealing with data transfer by the Data Link Layer, shall apply. The mapping between this service definition and the protocol elements specified in Section is given in Section .

4.3.2 Data Link Layer Protocol

In terms of HDLC, the AB 3418 Data Link Layer protocol is based on the Unbalanced Connectionless Class (UCC) of procedures defined in ISO/IEC 7809 with HDLC optional functions #7 applied for multi-octet addressing and #15.1 for start/stop transmission with basic transparency. This is designated as UCC-7,15.1.

Those clauses of ISO/IEC 3309, 4335, and 7809 dealing with the following do not apply to the AB 3418 protocol:

1) synchronous transmission;
2) classes and associated modes other than UCC; and
3) HDLC optional functions other than 7 and 15.1.

4.3.2.1 Frame Structure

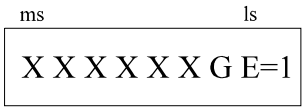
The frame structure shall be as defined in ISO/IEC 3309 and illustrated in Appendix A.

Transmission shall be in start/stop mode with basic transparency applied. The other transparency modes do not apply.

The address field of data link layer frames can be used as single or extended byte addressing, as provided for in Clause 5.1 of ISO/IEC 3309, and incorporates support for

group addressing. In its simplest form, a single byte is used to define an address range of 1 to 63. In its extended form, up to five bytes can be used to define an address range of from 1 to 2^{34} (for purposes of mapping this into a Network address, the values should be limited to 999,999). The low order bit of the first and second byte of an address can be set to 0 to indicate that the next byte is part of the address field. The second low order bit of the first byte indicates that the frame is intended only for a selected group of addresses previously defined. Figures 1 through 3 illustrate how the address field can be used.

Figure 1 illustrates a single byte address field. With bit 0 and bit 1 set to 1 and 0 respectively, the upper 6 bits can be used to address stations 1 to 63. Address 0 is never assigned. If the second low order bit is set to 1, the frame is intended for a group of secondary addresses that has been previously defined in other frames. Group address 63 (0xff) is reserved for the "all stations" group address. If the low order bit is set to 0, the address field consists of this byte and, at least, the next byte.

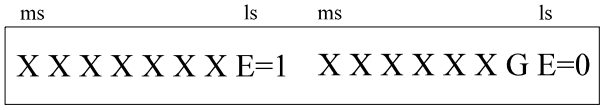


G = 1 for Group Address
E = 1 for Non-Extended Address

Single Byte Address Field

Figure 1

Figure 2 indicates the structure of a two byte address field. The low order bit of the first byte is set to 0 to indicate an extended field and the low order bit of the second byte is set to 1 to indicate the last byte of address field. The complete address consists of the seven bits of the second byte concatenated in front of the six bits of the first byte. The second low order bit of the first byte is still used to indicate a group address for broadcast messages.

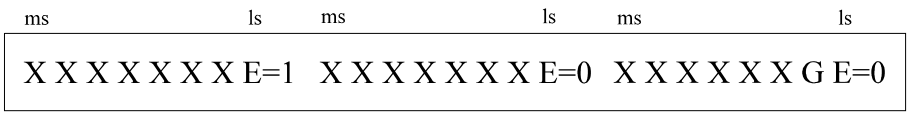


Two Byte Address Field

Figure 2

Figure 3 indicates the structure of a three byte address field. Similarly, four or five byte addresses can be formed by adding one or two bytes of similar format to the second byte in the three byte example. The maximum number of bytes in the address field is limited to five and the low order bit of the fifth byte is therefore always set to 1. When used, the upper seven bits of the fifth byte would be concatenated to the previous 27 bits of the first four bytes to provide an address space of 2^{34}.

The order of byte transmission shall be from least significant to most significant.



Three Byte Address Field

Figure 3

Support for 1 byte addressing is mandatory. Recognition of extended addressing is mandatory. Support for multi-byte addressing shall be provisional. Transmit and receive shall support the same level of addressing. If an address comprised of less than five bytes is received, the high order bits of the address are assumed to be 0's. The exception to this rule is the "all stations" group address which is always a 1 byte address.

The control field shall be one octet in length; it shall not be extended.

The 16-bit Frame Checking Sequence (FCS) procedure defined in Clause 4.6.2 of ISO/IEC 3309 shall be used.

4.3.2.2 Supported Frame Types

The AB 3418 protocol shall make use of the following HDLC frames types, as defined in ISO/IEC 4335 and in ISO/IEC 7809 for use with the UCC procedures:

Commands:	Responses:
Unnumbered Information (UI)	Unnumbered Information (UI)
Unnumbered Poll (UP)	

Encoding for the control field of the above frames is given in ISO/IEC 4335. The Poll/Final bit of the control field shall be used as described in the referenced standards except that the Poll bit shall always be set in an unnumbered poll. An unnumbered poll shall never be used with a broadcast address. The UI control byte is 0x13 (single address) or 0x03 (broadcast) while the UP control byte is 0x33 (single address).

4.3.2.3 Procedures

Transmission of frames on the link shall be in Unbalanced mode as described in the Introduction of ISO/IEC 4335 and Clause 6 of ISO/IEC 7809. That is, transmission shall be controlled by the Data Link layer of the station designated as the Primary station (referred to as the "control" station in ISO/IEC 7809) on that link and shall be responded to by a singly-addressed Secondary station (referred to as the "tributary" station in ISO/IEC 7809). Transmission by the Primary station to a group address shall have no response (i.e., all group communications are sent in a UI with P=0).

Provisionally, the Data Link layer of a primary station shall support a scheduler that periodically signals the application layer that it is time to send a polling message in the next available frame. The unnumbered poll control frame type is used for this control purpose.

A Secondary station shall transmit only one UI response frame per respond opportunity. Clause 6.4.2.2 of ISO/IEC 7809, which states that the last UI response frame (F-bit=1) must have an information field length of zero, shall be ignored.

When a switched connection (e.g., a telephone connection) is used to establish the link, the roles of Primary and Secondary stations shall be based on which station initiated the connection; the Primary shall be the calling station while the Secondary shall be the called station. The procedures for establishing a switched connection are beyond the scope of this Standard. However, Application Layer messages are defined to provide authentication of the parties participating in a switched connection.

4.3.2.4 Protocol Parameters

The following protocol parameters shall be supported:

1) Length of information field: a system conforming to this Standard shall support an information-field length of at least 515 octets; a system supporting lengths greater than this value shall also state what lengths are supported.

There are four timers normally associated with the Data Link Layer; T1 through T4. They shall be setable in the range of 1 to 2147483647 milliseconds, by 1. Their context only applies to the Data Link Layer; not other layers.

T1 - This specifies the maximum time to wait for acknowledgment of a frame.

T2 - This specifies the maximum time to wait before sending an acknowledgment of a sequenced frame. A value of 0 means that there will be no delay in acknowledgment generation. This timer insures that secondary starts a response so that it is received by a primary before T1 times out (T2 < T1).

T3 - This specifies the time to wait before considering a link disconnected.

T4 - This specifies the maximum time to allow without frames being exchanged on the data link. A value of 0x7FFFFFFH indicates that no idle timer is being kept.

When using a full duplex FSK Modem Interface with once per second communications, the following timer values are recommended:

T1 - 20 ms.
T2 - 10 ms. (CTS delay + 4 ms processing time)
T3 - 30 ms.

T4 - Not Applicable

4.4 Network Layer Definition

4.4.1 Protocol Identification

The protocol identification function allows for multiple Network Layer protocols to be distinguished from each other. In the case of the NTCIP, a system may support both Class A and Class B communications and the associated protocols. The AB 3418 protocol supports only Class B communications, but a protocol identification byte is still required so that AB 3418 systems are compatible with NTCIP systems.

ISO/IEC TR 9577 defines an initial protocol (in the Network Layer) as that protocol "operating directly over the Data Link Layer". This protocol is identified by the *Initial Protocol Identifier* (IPI). The IPI is the first byte of information passed between the Network and Data Link Layers in the user data parameter of a DL-UNITDATA primitive. It is through this IPI that the NTCIP Network Layer can distinguish between its two protocols.

The value of the IPI used for the AB 3418 protocol is as shown in Figure 4.

Bit Pattern 7 6 5 4 3 2 1 0	Protocol
1 1 0 0 0 0 0 0	AB3418 Protocol

Initial Protocol Identifier (IPI) for the AB3418 Protocol

Figure 4

4.4.2 Class B Communications

Class B communications take place between systems on the same physical link. Therefore, little functionality is needed in the Network Layer to convey real-time Application Layer messages which by design are not longer than one packet.

4.4.2.1 Network Layer Service Definition

The service provided when supporting Class B communications is the connectionless-mode service (CLNS) as defined in CCITT Rec. X.213 | ISO/IEC 8348, Clauses 1-7 (general) and 15-19. Within these clauses, those aspects dealing with Quality of Service shall not apply (this includes all of Clause 17 and applicable parts of the other clauses). In particular, the following aspects of these clauses are noted.

1) Clause 15 describes the features of the CLNS: all implementations shall support an NSDU length (i.e., the length of the NS-User-Data parameter) of at least the

DLSDU size (given above) minus one byte (to account for the one byte Class B header).

2) Clause 16, dealing with the model of the CLNS, shall apply with the additional assumptions that the service shall not duplicate SDUs nor exchange the order of SDUs.

3) Clause 18, dealing with the sequence of primitives, shall apply.
4) Clause 19, dealing with data transfer by the Network Layer, shall apply. The relationship of the service definition to the protocol elements is defined below.

4.4.2.2 Class B Communications Protocol

This protocol shall use the DL-UNITDATA primitives for transfer of its packets. The DLS-User-Data parameter of these primitives shall carry the packets defined by this protocol.

The packet structure for this protocol is given in figure 5.

Figure 5

Only one packet type is defined by this protocol: a Data packet.

This protocol takes the contents in the NS-User-Data parameter of an N-UNITDATA request primitive and embeds it in the higher-layer information field of the Data packet. The resulting packet is then passed down to the Data Link Layer as described above.

On receipt of a Data packet, the opposite mapping shall be performed.

The following protocol parameters shall be supported:

1) Length of higher-layer information field: a system conforming to this Standard shall support a higher-layer information-field length of at least the DLSDU size (given above) minus one byte (to account for the one byte Class B header); a system supporting lengths greater than this value shall also state what lengths are supported.

4.4.2.3 Mapping of Protocol to Service

The mapping of this protocol to the CLNS provides for:

1) The mapping between N-UNITDATA primitives to Data packets;
2) The source and destination addresses of N-UNITDATA request primitives are not carried by this protocol;

3) The mapping between the NS-User-Data parameter in N-UNITDATA primitives to the higher-layer information field in Data packets.

4.5 Application Layer Definition

All application level messages start with a byte that indicates the message type. This byte corresponds to the first byte of the protocol data unit (PDU) currently defined by the NTCIP protocol. This byte is required in all application messages and follows the last byte of the network layer IPI (see section 4.4). This byte has several "bit fields" defined as follows.

MESSAGE TYPE			
BITS	**VALUE**	**NAME**	**DESCRIPTION**
7	1	STMP Format	This bit must be set to 1 to conform to STMP
6-4	000	Get request	This value indicates a GET request is contained in the packet.
	001	Set request	This value indicates a SET request is contained in the packet
	010	Set request - no reply	This value indicates a SET request that requires no reply, is contained in the packet
	011	Trap response	This value indicates a TRAP response is contained in the packet.
	100	Get response	This value indicates a response to a GET request is contained in the packet (positive ACK).
	101	Set response	This value indicates a response to a SET request is contained in the packet (positive ACK).
	110	Get error response	This value indicates an error response to a GET request is contained in the packet.
	111	Set error response	This value indicates an error response to a SET request is contained in the packet.
3-0	0001-1101	Message (object) number	This value indicates which message number is being communicated in the packet. Values 0, 14 and 15 are reserved by NTCIP.

The bytes following the first byte in the application level PDU are variable in length and correspond to the information specific to the message number identified in bits 3-0 of the first byte of the application level PDU.

Response messages to GET and SET requests shall contain appropriate information for the specific message number indicated. All error response messages shall contain an error number (byte) and index number (byte) that conforms to the following definition.

ERROR RESPONSE DEFINITION			
ERROR		**INDEX**	
1	tooBig	0	The received PDU was different than expected.
2	noSuchName	1	The message type is not implemented.
3	badValue	Field Number (1-n)	The value of the specified field number is not valid (out of range). The INDEX represents the first field (left to right) that contains an error. This error should never be received for a GET request.
4	readOnly	Field Number (1-n)	A SET request was received for a field that is read only (not settable). The INDEX represents the first field number that is read only. This error should never be received for a GET request.
5	genErr	Field Number (1-n)	This error response indicates that some other error has occurred that does not conform to one of the errors specified above.

In AB 3418, fields correspond to bytes in transmission order, starting with the first byte after the message type byte.

4.5.1 Controller Identification Message (1)

The intent of this message is to identify the controller type, its communications capabilities, and other pertinent information. This message would typically be used when a controller initially starts up so that it properly identifies itself to the system (master or central).

This message shall cause the controller to immediately return controller identification information. Either a get response or get error response shall be returned by the controller.

The get request PDU shall contain the following byte.

GET CONTROLLER IDENTIFICATION REQUEST		
BYTE	**VALUE (HEX)**	**DESCRIPTION**

01	81	"GET CONTROLLER ID REQUEST" Message Type

The get response (no error) shall be returned only if byte 1 is “81”. The get response message is as follows. This is a variable length message that cannot exceed 512 bytes total length.

GET CONTROLLER ID RESPONSE		
BYTE	**VALUE (HEX)**	**DESCRIPTION**
01	C1	"GET CONTROLLER ID RESPONSE - No Error" Message Type
02	LENGTH	Number of bytes in message bytes 3 to (N+9)
03	LENGTH	Number of bytes in manufacturer's ID
4 to m-1	NAME	ASCII string with manufacturer's ID
m	LENGTH	Number of bytes in model ID
m+1 to N-1	MODEL	ASCII string with model ID
N	9	Number of bytes in protocol revision ID
N+1 to N+9	"AB3418 V1"	ASCII string with protocol revision ID

The protocol revision string shall contain only one space character, that being between the "8" and "V".

The get error response shall be returned if any error is encountered in the get request message. The following errors are possible: noSuchName (controller does not conform to AB 3418, or the NTCIP dynamic message has not been defined), genErr for any other error that needs reporting concerning this message.

The get error response shall be formatted as follows:

BYTE	**VALUE (HEX)**	**DESCRIPTION**
01	E1	"GET CONTROLLER ID ERROR RESPONSE" Message Type
02	ERROR	Error Number (2,5)

03	INDEX	Index Number (1)

4.5.2 Set Time Message (2)

This message shall cause the controller to immediately reset its time-of-day clock to match the parameters received. If the message is not a broadcast (i.e. set request with no response) then either a set response, or a set error response shall be returned. If the message is a broadcast then no response shall be transmitted (even if the message contains errors). If the message has an error it shall be discarded in its entirety.

The set request PDU shall contain the following bytes.

SET TIME REQUEST		
BYTE	**VALUE (HEX)**	**DESCRIPTION**
01	92	"SET TIME REQUEST" Message Type
	A2	"SET TIME REQUEST - No Response" Message Type
02	DOW	Day of week (1-7) 1= Sunday
03	MONTH	Month (1-12) 1 = January
04	DOM	Day of month (1-31)
05	YEAR	Last two digits of year (00-99); 95=1995, 0=2000, 94=2094
06	HOUR	Hour (0-23)
07	MIN	Minute (0-59)
08	SEC	Seconds (0-59)
09	TENTHS	Tenth Second (0-9)

The set response (no error) shall be returned only if byte 1 is “92” and there are no errors in the data fields. The set response messages is as follows:

SET TIME RESPONSE		
BYTE	**VALUE (HEX)**	**DESCRIPTION**

01	D2	"SET TIME RESPONSE - No Error" Message Type

The set error response shall be returned if any error is encountered in the set request message. The following errors are possible: tooBig, noSuchName (controller does not conform to AB 3418, or NTCIP dynamic message has not been defined), badValue (if any field contains data out of range, then the INDEX shall be set to the field number (1-8) of the bad data), genErr for any other error that needs reporting concerning this message.

The set error response shall be formatted as follows.

BYTE	**VALUE (HEX)**	**DESCRIPTION**
01	F2	"SET TIME ERROR RESPONSE" Message Type
02	ERROR	Error Number (1-5)
03	INDEX	Index Number (0-8)

4.5.3 Set Pattern Message (3)

This message shall cause the controller to immediately change to the specified timing pattern or mode of operation. If the message is not a broadcast (i.e. set request with no response) then either a set response, or a set error response shall be returned. If the message is a set request with no response then no response shall be transmitted (even if the message contains errors). If the message has an error it shall be discarded in its entirety.

The set pattern request PDU shall contain the following bytes.

SET PATTERN REQUEST		
BYTE	**VALUE (HEX)**	**DESCRIPTION**
01	93	"SET PATTERN REQUEST" Message Type
	A3	"SET PATTERN REQUEST - No Response" Message Type
02	PATTERN	Pattern number (0-255); 0 Standby, 251-253 reserved, 254 Flash, 255 Free

Standby mode means the controller shall use a pattern or mode selected by the local time-of-day schedule rather than one instructed by the master. Free mode means the controller is to operate uncoordinated.

It is not necessary for the controller to support 250 patterns. If a get pattern request contains an unimplemented pattern number, the controller shall return a Type 3 (badValue) error response and remain in the current pattern.

The set response (no error) shall be returned only if byte 1 is “92” and there are no errors in the data fields. The set pattern response message is as follows:

SET PATTERN RESPONSE		
BYTE	**VALUE (HEX)**	**DESCRIPTION**
01	D3	"SET PATTERN RESPONSE - No Error" Message Type

The set error response shall be returned if any error is encountered in the set request message. The following errors are possible: tooBig, noSuchName (controller does not conform to AB 3418, or NTCIP dynamic message has not been defined), badValue (if any field contains data out of range, then the INDEX shall be set to the field number (1) of the bad data), genErr for any other error that needs reporting concerning this message.
The set error response shall be formatted as follows.

BYTE	**VALUE (HEX)**	**DESCRIPTION**
01	F3	"SET PATTERN ERROR RESPONSE" Message Type
02	ERROR	Error Number (1-5)
03	INDEX	Index Number (0-1)

4.5.4 Get Short Status Message (4)

This message shall cause the controller to immediately return its green phase and controller status information. Either a get response, or a get error response will be returned.
The get request PDU shall contain the following byte.

GET SHORT STATUS REQUEST		
BYTE	**VALUE (HEX)**	**DESCRIPTION**
01	84	"GET SHORT STATUS REQUEST" Message Type

The get response (no error) shall be returned only if byte 1 is “84”. The get response message is as follows.

GET SHORT STATUS RESPONSE		
BYTE	**VALUE (HEX)**	**DESCRIPTION**
01	C4	"GET SHORT STATUS RESPONSE - No Error" Message Type
02	GREEN 1-8	Green Phases for phases 1-8 (see definition below)
03	STATUS	Controller status bits (see definition below)
04	PATTERN	Current pattern number

The green phases byte is defined as follows.

GREEN PHASES BYTE	
BIT	**DESCRIPTION**
7	If bit = 1 then Phase 8 is green, otherwise it is not green
6	If bit = 1 then Phase 7 is green, otherwise it is not green
5	If bit = 1 then Phase 6 is green, otherwise it is not green
4	If bit = 1 then Phase 5 is green, otherwise it is not green
3	If bit = 1 then Phase 4 is green, otherwise it is not green
2	If bit = 1 then Phase 3 is green, otherwise it is not green
1	If bit = 1 then Phase 2 is green, otherwise it is not green
0	If bit = 1 then Phase 1 is green, otherwise it is not green

The bits are defined in this order to allow for compatibility with NTCIP which allows for future growth in the number of phases that may be supported (more than 8).

The controller status byte is defined as follows.

CONTROLLER STATUS BYTE	
BIT	DESCRIPTION
7	If bit = 1 then controller has a critical alarm pending
6	If bit = 1 then controller has a non-critical alarm pending
5	If bit = 1 then controller has a detector fault pending
4	If bit = 1 then controller has a coordination alarm pending
3	If bit = 1 then controller is in local override mode
2	If bit = 1 then controller has passed local zero since last request
1	If bit = 1 then cabinet flash is occurring
0	If bit = 1 then controller is in preempt

The controller status bits shall be set as follows.

Critical Alarm Bit - may be set if at least any of the following conditions occur: the signal is off (black), stop time is active, or cabinet flash is active.

Non-critical Alarm Bit - may be set by any of several conditions including low priority preempt, cabinet door open, lamp out, etc.

Detector Fault Bit - shall be set if any detector is currently failed for any reason, including locked on, locked off, or chattering.

Coordination Alarm Bit - shall be set if the controller is not in the intended pattern or is not coordinated within three cycles after a coordination pattern is introduced. This bit shall not be set if the signal is in offset transition for less than three cycles, as may occur when the cycle is overrun due to a pedestrian call.

Local Override Bit **-** shall be set if manual control is enabled, or by some other means the controller is to ignore the pattern set by the master.

Local Zero Bit **-** shall be set if the signal is coordinated and the coordination cycle timer equaled zero at any time since the last "get short status request" was received.

Cabinet Flash Bit **-** shall be set when the controller's "cabinet flash" input circuit is active. This may have resulted from a tripped conflict monitor, manual flash, or police flash.

Preempt Bit - shall be set if the controller is in railroad or emergency vehicle preempt. Other types of preempt or transit priority can be flagged using the non-critical alarm bit.

The get error response shall be returned if any error is encountered in the get request message. The following errors are possible: noSuchName (controller does not conform to AB 3418, or NTCIP dynamic message has not been defined), genErr for any other error that needs reporting concerning this message.

The get error response shall be formatted as follows:

BYTE	**VALUE (HEX)**	**DESCRIPTION**
01	E4	"GET SHORT STATUS ERROR RESPONSE" Message Type
02	ERROR	Error Number (2,5)
03	INDEX	Index Number (1)

4.5.5 Get System Detector Data Message (5) - Optional

This message shall cause the controller to immediately return its system detector data. Either a get response, or a get error response shall be returned by the controller.

The get request PDU shall contain the following byte.

GET DETECTOR DATA REQUEST		
BYTE	**VALUE (HEX)**	**DESCRIPTION**
01	85	"GET DETECTOR DATA REQUEST" Message Type

The set response (no error) shall be returned only if byte 1 is “85”. The set response messages is as follows:

GET DETECTOR DATA RESPONSE		
BYTE	**VALUE (HEX)**	**DESCRIPTION**
01	C5	"GET DETECTOR DATA RESPONSE - No Error" Message Type
02	N-2	Byte count of following data (not including bytes 1, 2)
03	SEQ #	Sequence number of this sample (number increases each sample period)
04	PERIOD	Sample (collection) period in seconds (1-255) for this data sample
05	# DET	Number of system detectors in sample (0-125)
06	VOL #1	Volume from system detector #1
07	OCC #1	Occupancy from system detector #1 (see definition below)
…	…	… other detectors' volume & occupancy
N-1	VOL #X	Volume from system detector #X (last detector)
N	OCC #X	Occupancy from system detector #X (last detector)

The occupancy byte is encoded as a percentage from 0-100% with a resolution of 0.5%. The values 210-215 indicate error conditions as follows.

OCCUPANCY BYTE	
VALUE	**DESCRIPTION**
0-200	Detector occupancy in 0.5% increments
210	Stuck ON fault
211	Stuck OFF fault
212	Open Loop fault
213	Shorted Loop fault
214	Excessive Inductance fault

215	Overcount fault

The get error response shall be returned if any error is encountered in the get request message. The following errors are possible: noSuchName (controller does not support this message, or the NTCIP dynamic message has not been defined), genErr for any other error that needs reporting concerning this message.

The get error response shall be formatted as follows.

BYTE	**VALUE (HEX)**	**DESCRIPTION**
01	E5	"GET DETECTOR DATA ERROR RESPONSE" Message Type
02	ERROR	Error Number
03	INDEX	Index Number (1)

4.5.6 Future Messages (6-12)

Future messages may be defined by the AB 3418 committee. However it is the intent that the AB 3418 protocol defined here be a subset of the National Transportation Control/ITS Communication Protocol (NTCIP). It is envisioned that future enhancements will come from the NTCIP protocol and not AB 3418.

4.6 Controller as Master

The controller shall respond to command messages received from a master by sending the appropriate response message. The controller need not have the ability to initiate communications (i.e. act as a master and send command messages), but addition of this capability is not precluded.

4.7 Access to Multiple Protocols

If other protocols are provided in the controller software package, a convenient means shall be provided for the user to invoke alternative protocols.

Appendix A - Application Notes

A.1 Communications with Multiple Masters

It is normal for a controller to be connected to only one master. However, it is possible that a controller could be connected to two masters using two communications ports. One could provide communications with the owning agency's master using a dedicated communications protocol (not AB 3418) while the other allows another agency's master to also communicate with the controller using the AB 3418 protocol. The two agencies would need to cooperate in determining which master is to issue which commands. In this arrangement, one of the masters would likely be used only for monitoring.

Some masters communicate with controllers using a dial-up telephone link. The controller is connected to the master only when needed and usually only for a short period of time. The AB 3418 protocol supports dial-up links. Some software developers may offer the ability for two different masters, one using the AB 3418 protocol and one using another protocol, to dial-up the same controller at different times.

However, there is no requirement under AB 3418 for a controller to provide a dual protocol dial-up capability or a second communications port for use with two masters, and such capabilities cannot be counted on as being available in an AB 3418 compliant controller. If one agency has a master in communication with a controller, then another agency may not be able to also communicate directly with that controller despite AB 3418.

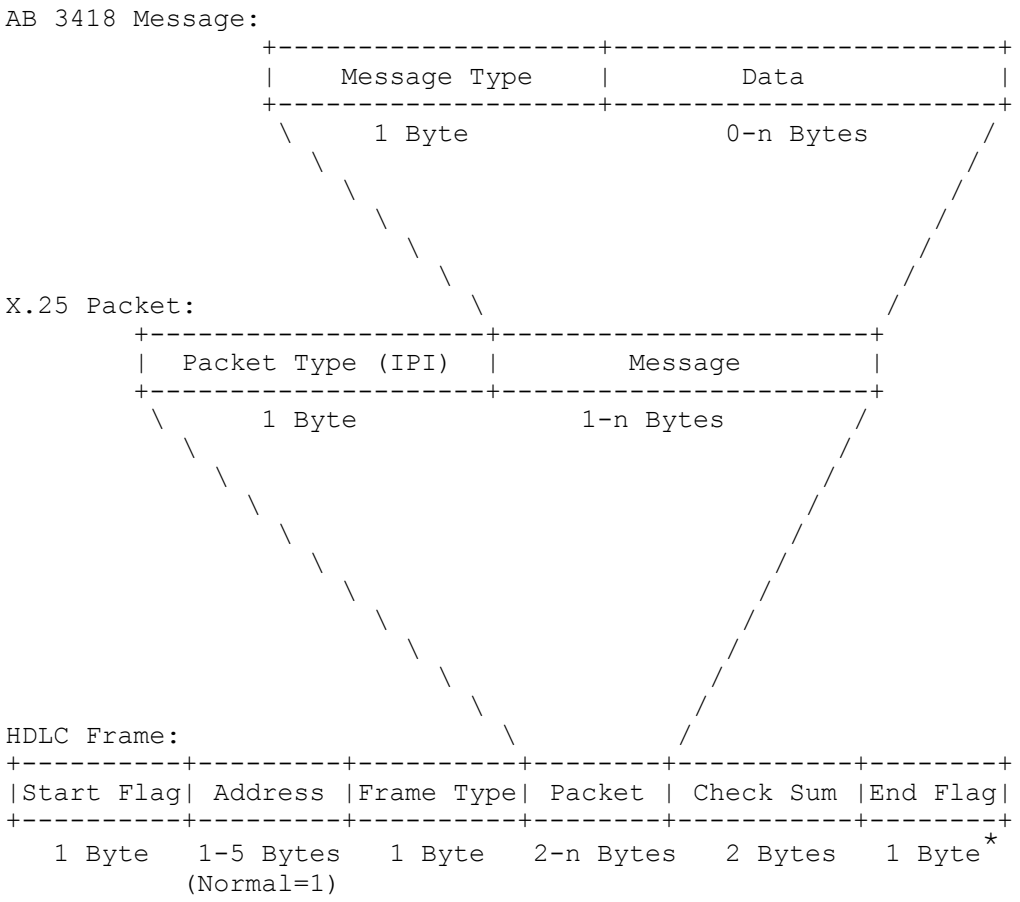
A.2 Summary of AB 3418 Messages

No.	Purpose	No. of Bytes in Request [1]	No. of Bytes in Response [1]
1	Get Controller Identification	1	16-512
2	Set Date and Time	9	1
3	Set Pattern	2	1
4	Get Short Status	1	4
5	Get Detector Data	1	5-505

[1] Includes the "message type" byte, but excludes other overhead (typically an additional seven bytes).

A.3 Overview of the AB 3418 Protocol Message Format

The following diagram shows the components of a complete AB 3418 message.



* May be combined with start flag of next message under certain circumstances.

Appendix B - The Full Text of AB 3418

The following is the full text of Assembly Bill No. 3418.

CHAPTER 1297

An act to amend Section 21401 of the Vehicle Code, relating to vehicles.

[Became law without Governor's signature. Filed with
Secretary of State October 4, 1994.]

LEGISLATIVE COUNSEL'S DIGEST

AB 3418, Weggeland. Vehicles: traffic control signals.

(1) Existing law requires that only those official traffic control devices that conform to the uniform standards and specifications promulgated by the Department of Transportation be placed upon a street or highway, except as specified.

This bill would require that any traffic signal controller that is newly installed or upgraded by the department or a local authority be of a standard traffic signal communication protocol capable of two-way communication. Because the bill would impose new duties on local authorities, it would create a state-mandated local program.

(2) The California Constitution requires the state to reimburse local agencies and school districts for certain costs mandated by the state. Statutory provisions establish procedures for making that reimbursement, including the creation of a State Mandates Claims Fund to pay the costs of mandates which do not exceed $1,000,000 statewide and other procedures for claims whose statewide costs exceed $1,000,000.

This bill would provide that, if the Commission on State Mandates determines that this bill contains costs mandated by the state, reimbursement for those costs shall be made pursuant to those statutory procedures and, if the statewide cost does not exceed $1,000,000, shall be made from the State Mandates Claims Fund.

The people of the State of California do enact as follows:

SECTION 1. By enacting this legislation, it is the intent of the Legislature to facilitate traffic signal coordination and monitoring of traffic signal operations.

SEC. 2. Section 21401 of the Vehicle Code is amended to read:

21401. (a) Except as provided in Section 21374, only those official traffic control devices that conform to the uniform standards and specifications promulgated by the Department of Transportation shall be placed upon a street or highway.

(b) Any traffic signal controller that is newly installed or upgraded by the Department of Transportation or a local authority after January 1, 1996, shall be of a standard traffic signal communication protocol capable of two-way communications.

SEC. 3. Notwithstanding Section 17610 of the Government Code, if the Commission on State Mandates determines that this act contains costs mandated by the state, reimbursement to local agencies and school districts for those costs shall be made pursuant to Part 7 (commencing with Section 17500) of Division 4 of Title 2 of the Government Code. If the

statewide cost of the claim for reimbursement does not exceed one million dollars ($1,000,000), reimbursement shall be made from the State Mandates Claims Fund. Notwithstanding Section 17380 of the Government Code, unless otherwise specified in this act, the provisions of this act shall become operative on the same date that the act takes effect pursuant to the California Constitution.

Appendix C - Members of the AB 3418 Implementation Committee

Name	Organization
Chuck Perry (Chairman)	Caltrans Headquarters
Lawrence Tai (Secretary)	Riverside County
Douglas Acker	Los Angeles County
Gerald Bloodgood	BI Tran Systems
Alan Clelland	JHK & Associates
Gary Duncan	Econolite
Don Dey	Menlo Park
Mike Evans [1]	Intersection Development Corporation
Charles Felix	San Jose
Craig Gardner [1]	Gardner Rowe Systems
Peter Liu	LA County MTA
Shawn Morrissey	Intersection Development Corporation
Anson Nordby	Los Angeles
Ahmad Rastegarpour [1]	Caltrans Headquarters
Sean Skehan [1]	Los Angeles
Jeff Spinazze [1]	Econolite
Warren Tighe	DKS Associates
Don Wood [1]	Santa Clara County

[1] Alternate member who attended some meetings.

Appendix D - References

The AB 3418 protocol specification directly references the following four Standards in its definition. This list represents the documents that are pertinent to a full understanding of the complete definition and operation. Copies may be obtained from the American National Standards Institute (ANSI) at:

American National Standards Institute
11 West 42nd Street
New York, New York 10036
Telephone (212) 642-4900
FAX (212) 302-1286

ISO/IEC 3309: 1993 (E)

Information technology - Telecommunications and information exchange between systems - High level data link control (HDLC) procedures - Frame structure

This International Standard specifies the frame structure for data communication systems using bit-oriented high-level data link control (HDLC) procedures. It defines the relative positions of the various components of the basic frame and the bit combination for the frame delimiting sequence (flag). The mechanisms used to achieve bit pattern independence (transparency) are also defined. In addition, two frame checking sequences (FCS) are specified; the rules for address field extension are defined; and the addressing conventions available are described.

ISO/IEC 4335: 1993 (E)

Information technology - Telecommunications and information exchange between systems - High level data link control (HDLC) procedures - Elements of procedures

This International Standard specifies elements of data link control procedures for synchronous or start/stop, code-transparent data transmission using the HDLC frame structure specified in ISO 3309 and independent frame numbering in both directions.

ISO/IEC 7809: 1993 (E)

Information technology - Telecommunications and information exchange between systems - High level data link control (HDLC) procedures - Classes of procedures

This International Standard describes the HDLC unbalanced classes of procedures and the HDLC balanced class of procedures for synchronous or start/stop data transmission.

ISO/IEC 8208: 1993 (E)

Information technology - Data Communications - X.25 Packet Layer Protocol for Data Terminal Equipment

This International Standard specifies the procedures, formats and facilities at the Packet Layer for Data Terminal Equipment (DTE) operating in conformance with CCITT Recommendation X.25. Both Virtual Call and Permanent Virtual Circuit modes of operation are covered.